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NONPROGRAM VARIABLES IN THE APPLICATION OF PROGRAMED INSTRUCTION.

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TWO EXPERIMENTS WERE CONDUCTED TO ANALYZE THE SPECIFIC EXTERNAL FACTORS THAT CONTRIBUTE MOST SIGNIFICANTLY TO STUDENT LEARNING. THE THREE HYPOTHESES TESTED WERE--(1) LEARNING IS INCREASED WHEN AN EXPERIMENTER ACTIVELY AUGMENTS THE PROGRAM BY REPHRASING PROGRAM STATEMENTS AND BY BRANCHING THE STUDENT TO DIFFERENT PARTS OF THE PROGRAM WHEN THE STUDENT HAS DIFFICULTY WITH A PARTICULAR TOPIC, (2) LEARNING IS INCREASED WHEN THE EXPERIMENTER HAS ACCESS TO DETAILED DISPLAYS OF CURRENT POST STUDENT PERFORMANCE, DESIGNED TO ASSIST HIM IN DIAGNOSING STUDENT-LEARNING PROBLEMS, AND (3) LEARNING IS INCREASED BY ALLOWING THE STUDENT TO BRANCH VOLUNTARILY IN THE PROGRAM AT ANY TIME DURING THE INSTRUCTION. THE THREE NONPROGRAM VARIABLES USED WERE (1) EXPERIMENTER AUGMENTATION, (2) DIAGNOSTIC INFORMATION, AND (3) STUDENT CONTROL. TWO EXPERIMENTS WERE CARRIED OUT. IN THE FIRST EXPERIMENT, 53 RANDOMLY SELECTED STUDENTS RECEIVED 6 EXPERIMENTAL TREATMENTS. EACH SUBJECT WAS DIRECTED TO APPROPRIATE PAGES IN HIS PROGRAM BY A DIGITAL DISPLAY ON HIS RESPONSE DEVICE. HE RESPONDED TO MULTIPLE CHOICE ITEMS BY PRESSING A BUTTON. FEEDBACK WAS GIVEN BY A RED/GREEN LIGHT ARRANGEMENT. THE COMPUTER RETAINED INFORMATION ON THE SUBJECT'S PERFORMANCE. THE SECOND EXPERIMENT STUDIED THE NONPROGRAM VARIABLES WITH 104 SUBJECTS IN 4 HIGH SCHOOL CLASSROOMS, WITH 4 TEACHERS SERVING AS EXPERIMENTERS. SUBJECTS WITH A PASSIVE EXPERIMENTER AND ADDITIONAL MATERIALS WERE (1) TOLD TO USE THE MATERIALS AS THEY SAW FIT, AND (2) GIVEN THE PROGRAM BOOKLET. SUBJECTS WITH AN ACTIVE EXPERIMENTER WERE GIVEN ONLY THE PROGRAM BOOKLET FOR USE IN THE CLASSROOM. THE STUDY DID NOT FIND THAT PROGRAM EFFECTIVENESS WAS DETERMINED BY VARIABLES NOT DIRECTLY UNDER PROGRAM CONTROL AS SUGGESTED BY THE HYPOTHESES SUBJECTED TO TEST. (HB)

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Final Report

Non-Program Variables in the Application of Programmed Instruction

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TECHNICAL MEMORANDUM

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Final Report

Non-Program Variables in the Application of Programmed Instruction

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ABSTRACT

Recent research suggests that programmed instruction is far from the self-contained, self-sufficient instructional vehicle it is often assumed to be. The effectiveness of even the most carefully prepared program is largely governed by factors external to the program itself, such as the way in which the program is applied by the teacher and the degree of control the student has over the program.

The purpose of this experiment was to analyze the specific factors, operating in conjunction with but external to the program itself, that contribute most significantly to student learning. The major hypotheses of the study were:

1. Learning is increased when an experimenter (teacher) actively augments the program by rephrasing program statements and by branching the student to different parts of the program when the student has difficulty with a particular topic.

2. Learning is increased when the experimenter has access to detailed displays of current and past student performance, designed to assist him in diagnosing student learning problems.

3. Learning is increased by allowing the student to branch voluntarily in the program at any time during the instruction.

Data from both experiments indicated that the teachers were not able to contribute to learning in the programmed learning situation. Possible explanations are: (a) the teachers did not have enough time with each student to affect learning; and (b) they were used in a role that did not make full use of their capabilities. It appears that teachers can play an effective part in programmed instruction only when their role has been empirically developed as an integral, interacting part of the total instructional system including the students, the program, and any other classroom resources.

Student control over the program was not exercised, and therefore had no chance to influence learning. Possibly in future studies the students could be motivated to review by allowing them to ask questions in their natural language, or by using preprogrammed remedial loops as "penalties" for students who advance before they have thoroughly mastered each topic.

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I. PROBLEM

Most research in programmed instruction has been concerned with variables in the design of the program itself (Silberman, 1962). Experiments have been focused on such variables as response mode, reinforcement, and program format. Implicit in this research on program variables is a view of programmed instruction as a self-contained, self-sufficient instructional vehicle. Such a view seems unrealistic, however, in the light of a recent report that most teachers who use programmed instruction in the classroom actively augment the program with supplementary discussion (Center for Programed Instruction, 1963). A recent SDC study (Silberman, et al., 1964) suggests that the role of the teacher in augmenting the program, and the extent of his knowledge about student performance have a distinct impact on the program's effectiveness and its responsiveness to individual differences. Furthermore, earlier SDC research, using a computer-controlled branching procedure (Coulson, et al., 1962), indicated that preprogrammed branches do not adequately provide for student differences, and that the student must be given some control over the program.

In short, previous research has suggested that program effectiveness is determined to an important degree by variables not directly under program control. The present study was designed to assess the contributions to student learning of three non-program variables in the application of programmed instruction.

- Experimenter Augmentation. Two conditions of this variable permitted an assessment of the contribution of the experimenter in augmenting the program. The Passive Experimenter provided no instruction assistance; the Active Experimenter supplemented the program's instruction by clarifying material and by deciding when and where to branch students within the program.

- Diagnostic Information. Two conditions of this variable yielded an evaluation of the contribution of providing diagnostic information to the experimenter who augmented the program. In the Minimum Information condition, the experimenter was limited to data obtained through general observation of the students and from student questions and gratuitous comments; the experimenter could not get detailed information about individual students' responses. In the Maximum Information condition, the experimenter received data on student performance designed to assist him in diagnosing student learning problems.

- Student Control. The two conditions here permitted an assessment of the effects of giving the student voluntary control over his program sequence. The No Control condition required the student to follow a predetermined sequence; the Control condition allowed the student to branch himself to a new topic at any point in the program by using an index of topics.

To insure generalizability of laboratory findings to the classroom, combinations of the three variables were to be studied both in the laboratory (Experiment I) and in classrooms (Experiment II).*

II. RELATED RESEARCH

Relatively few studies have included human augmentation of programmed materials as an experimental condition. Where relevant research has been conducted, there is conflicting evidence about the effect of such augmentation on student learning.

Klaus and Lumsdaine (1960) compared teacher-plus-program with program alone, with the teacher's function restricted to lecture-recitation for an entire class. They found that the teacher did not add to the level of achievement produced by the program.

However, some contradictory observations were made in recent SDC studies that used a computer-based instructional system and allowed experimenter interaction with students. This exploratory research (Silberman, et al., 1964) suggested that the teacher may contribute significantly to student learning from the program, provided the teacher's function includes diagnosis of student performance as well as the program-clarification role. It appeared that, unless the teacher's interaction is directly related to the student's difficulty, little help is provided beyond the supportive effect of teacher attention.

Other reported findings related to recent observations in the SDC laboratory and to the proposed study are that optional student control over the sequence of programmed material may be an important factor in student learning (Briggs, 1963) and in student motivation (Mager, 1961). Observations obtained in an earlier study in the SDC laboratory (Coulson, et al., 1962) suggested that adding student-controlled branching to computer-controlled branching improved learning.

III. OBJECTIVES

The major hypothesis of this study was that each of the three procedures designed to increase responsiveness of programmed instruction would improve student performance. Thus, it was predicted that learning with active experimenter augmentation would be superior to learning without augmentation; that student learning with full diagnostic information available to the experimenter would exceed the learning without such information; and that learning with voluntary student control over program sequence would exceed that without control.

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*As it later developed, the results of Experiment I led to a change in design for Experiment II, as described in a subsequent section of this report.

It was further hypothesized that the effects of these three elements of responsiveness to individual differences would be cumulative. That is, instruction with active experimenter and full diagnostic information would be superior to instruction with active experimenter but without diagnostic information, and instruction with active experimenter and diagnostic information and student control would be the most effective.

IV. EXPERIMENT I

In Experiment I, the three non-program variables were studied in System Development Corporation's computer-based laboratory. Because each variable had two levels, eight treatment conditions were possible. However, two conditions would be superfluous, since the conditions containing the passive experimenter do not involve the information variable. Therefore, the eight possible treatment conditions were collapsed to the six listed below.

(1) Passive Experimenter, No Student Control
(2) Passive Experimenter, Student Control
(3) Active Experimenter, Minimum Information, No Student Control
(4) Active Experimenter, Minimum Information, Student Control
(5) Active Experimenter, Maximum Information, No Student Control
(6) Active Experimenter, Maximum Information, Student Control

In testing the hypotheses for this study the following comparisons were required:

Comparison	Groups Compared
Active vs. passive experimenter	3, 4, 5, 6 vs. 1, 2
Control vs. no control	2, 4, 6 vs. 1, 3, 5
Maximum vs. minimum information	5, 6, vs. 3, 4
Cumulative effects	6 vs. (5, 4) vs. (2, 3) vs. 1

A. Method

All subjects in the experiment received a geometry pretest in two parts (see Appendix A). Part A of the pretest covered information prerequisite to the program, and was used to screen out students who lacked the necessary entry skills. Part B, which presented questions closely related to the program, was used to screen out students who already had many of the skills covered by the program.

1. Subjects. Of 131 available high school students who had already completed one semester of plane geometry, 17 were eliminated on the basis of pretest scores. Fifty-three of the remaining students were randomly selected for assignment to the six experimental treatments.

2. Program. The program given to all experimental groups consisted of 391 frames, on geometric inequalities, in the form of printed booklets. These materials were developed in SDC's earlier exploratory study (Coulson, 1964). Geometry was selected for the proposed study because it combines both verbal and symbolic skills, and because it requires problem-solving behavior as well as rote learning.

Topics covered by the program included (a) the use of symbolic notation for expressing inequality statements, (b) application of the arithmetic axioms for combining inequality statements, (c) derivation and application of other geometric postulates and theorems, and (d) the formulation of logical sequences of geometric statements constituting formal proofs to geometric theorems.

Items contained in the program were of several major types:

- Content items: These frames, constituting the bulk of the program, contained all the basic information on the topics covered by the program. In most cases a content item presented a single idea, and might or might not require a response. Where a response was required, the solution was cued in that same item or in preceding items.

- Summary items: A summary item in textual form followed the content items on each topic in the program. This item did not contain questions, but summarized the highlights of the materials covered by the content items for that topic. The major purpose of the summary was to provide the student with a digest or overview of the topic that he had just covered in more detailed fashion.

- Relational items: The relational item was designed to give the student an even broader perspective of the topic he was studying, by showing how this topic related to others covered in the program or in earlier mathematical studies. For example, one of the arithmetic axioms of inequality ("unequals plus unequals of the same order gives unequals of the same order") was presented alongside several other arithmetic axioms of inequality, to point out similarities and critical differences among the axioms.

- Diagnostic items: One or more diagnostic items were included for each major topic covered by the program. These were true test items, with plausible distractors and minimal cueing, to provide a reliable evaluation of the student's knowledge of the topic. The results of these evaluations could be used by the student to gauge his own progress, or by the experimenter to assess the student's learning needs, depending on the experimental learning conditions prescribed for that student.

3. Criterion test. The criterion test developed in earlier SDC research on geometry (Coulson, 1964) was used as the posttest. Items were classified (on the basis of agreement by three independent judges) according to the amount and type of transfer of training required for the solution. One category required answers essentially identical to those elicited in the program. A second category required application to specific problems of theorems and axioms presented in the program. The third category involved the synthesis of response elements to form proofs of geometric theorems not seen previously by the students. Every major topic in the program was covered by at least one item in each of these three categories.

An item analysis of the test had been performed on the basis of responses by 64 students who participated in an earlier SDC study, and who received the same geometry program used in the present research. Items showing low correlation with the total test were eliminated.

The final test contained 33 multiple-choice questions, five completion questions, and six proofs to be completed. Because the completion questions involved multiple answers, the total possible score was 64.

4. Procedures. Subjects received instruction in groups of 20. Treatment conditions 1 and 2 were administered at the same time; the same held true for conditions 3 and 4, and for conditions 5 and 6. Subjects arrived at the laboratory immediately after their regular school day and remained for 50 to 75 minutes.

Each subject was directed to appropriate pages in his program by a digital display on his response device. The subject responded to multiple-choice items by pressing a button on the device; feedback was given by green ("correct") and red ("incorrect") lights plus a light alongside the correct answer button. The computer retained complete information on each subject's performance (e.g., items seen, responses made, and correctness of responses).

Each day, the subjects who had voluntary control over the sequencing of instruction were told to refer to the index on the side of the booth and review whenever they wished. The index contained a list of topics in the program, the pages on which instruction appeared, and the page number of the summary item for each topic. Subjects with voluntary control could either review an entire topic or could look only at the summary, as they chose. This voluntary deviation from the program sequence was not recorded by the computer, but was observed carefully by the experimenter and his associates. Subjects who had no voluntary control were told to never look back or ahead in the program.

For the two passive-experimenter conditions, the experimenter sat at a central desk during the instructional sessions, and answered questions only on the operation of the equipment.

For the minimum-information conditions, the experimenter was allowed to circulate within the laboratory, observing subjects' actions to isolate those seemingly in need of assistance, and was allowed to respond to any questions.

In the maximum-information conditions, the experimenter had special displays generated by a computer. When a subject answered a prespecified number of diagnostic questions incorrectly, a red light on a teacher's console was automatically lighted to inform the experimenter that the subject was having difficulty. The experimenter could then obtain more detailed information about that subject through a cathode-ray tube receiver. By pressing buttons on his console, the experimenter could find out: what item and topic the subject was on at that point, how many responses he had made, and how many errors he had made.

The active experimenter was allowed to assist subjects in three ways. First, he could restate the material to clarify a subject's misunderstanding; however, the experimenter could not bring in any new instruction (e.g., additional examples) beyond that contained in the program. Second, he could branch a subject to other sections of the program; branches were available to view summary items of a topic, to repeat an entire topic, or to repeat earlier segments of the program. Finally, he could work along with the student, step by step, as the student went through multi-step problems in the program.

Following the completion of the instructional program, subjects were administered the posttest on the next day.

5. Experimenter. A high school geometry teacher who had assisted in the preparation of the program and the posttest served as the experimenter. He was given training on procedures to be followed during the study, and on the operation of the teacher's equipment.

B. Results

Table 1 contains the means and standard deviations for posttest scores and for training times, for the six treatment conditions. Table 2 shows the results of Sheffe's S-test for multiple comparisons, for the various hypotheses (Sheffe, 1959).

From an inspection of Table 1 it is apparent that the six treatment conditions did not result in differential posttest scores. The S-tests in Table 2 verify this conclusion; none of the hypotheses was supported.

V. EXPERIMENT II

In Experiment II, the non-program variables were studied in four high school classrooms, with four teachers serving as the experimenters. As a result of findings in Experiment I, certain changes were made in procedures, as indicated below.

- Elimination of Student Control Variable. During Experiment I, it was regularly observed that subjects given the opportunity to control the sequencing of instruction failed to use this control. Despite repeated encouragement to either review earlier material or look ahead to later

Table 1

Means and Standard Deviations of Posttest Scores and Training Times for the Six Treatment Conditions (Experiment I)

Treatment Conditions	N		Posttest Scores	Training Times (mins.)
(1) Passive E, No Control	7	Mean	47.28	273.57
		SD	3.73	30.13
(2) Passive E, Control	10	Mean	46.40	280.90
		SD	8.54	32.26
(3) Active E, Min. Info., No Control	10	Mean	45.60	334.80
		SD	7.43	54.44
(4) Active E, Min. Info., Control	9	Mean	47.22	295.77
		SD	8.09	33.41
(5) Active E, Max. Info., No Control	9	Mean	50.11	323.55
		SD	6.04	50.48
(6) Active E, Max. Info., Control	8	Mean	49.25	340.62
		SD	10.69	38.17

Table 2

Sheffe's S-Test for Multiple Comparisons of Posttest Scores for the Six Treatment Conditions (Experiment I)

Treatments and Means					
(1)	(2)	(3)	(4)	(5)	(6)
47.28	46.40	45.60	47.22	50.11	49.25

Comparison	d	s_d	t*
3, 4, 5, 6 vs. 1, 2 (active vs. passive E)	1.20	3.74	.320
2, 4, 6 vs. 1, 3, 5 (control vs. no control)	.04	2.25	.017
5, 6 vs. 3, 4 (max. vs. min. information)	3.27	3.90	.838
1 vs. 2, 3 (cumulative effects)	.87	4.07	.213
2, 3 vs. 4, 5 (cumulative effects)	2.66	3.78	.703
4, 5 vs. 6 (cumulative effects)	.59	4.01	.147

*t must be greater than 3.39 for a significant difference with $\alpha = .05$

material, these subjects followed the predetermined sequence of instruction. Since subjects in the Control and No Control conditions did not differ, it was decided to eliminate this variable and to concentrate on the augmentation and information variables.

- Increase in Experimenters' Freedom to Augment Program. It was felt that the experimenter in Experiment I was hampered in his efforts to help subjects by artificial restrictions on the ways in which he could augment the program. Therefore, in Experiment II the experimenters were allowed to help subjects in any way they deemed appropriate.

- Addition of Materials for the Augmentation Variable. The experimenter in Experiment I indicated that he frequently found himself overloaded, when a number of subjects needed his assistance at the same time. Because he had to assist subjects individually, many subjects were forced to be idle until the experimenter could get to them. To avoid this situation in Experiment II, special materials were developed relating to the diagnostic questions in the program. The additional materials contained discussions of these questions, developing rationales for the correct answers. The experimenters were to hand out these additional materials to subjects who needed assistance, when the experimenters were temporarily unable to assist subjects individually due to an overload.

- Modifications in the Diagnostic Questions. In Experiment I, diagnostic questions immediately followed instructional materials for a topic. It appeared that this method was not sufficiently sensitive to subjects' learning difficulties, since the questions were so close in time to the instruction that they were extremely simple to answer. To obtain better assessment of learning difficulties, the diagnostic questions were placed after a number of topics that formed a natural unit. It was expected that confusion among related topics would be evident from incorrect answers to the modified diagnostic questions.

- Revisions to the Posttest. The posttest used in Experiment I was revised to eliminate questions that were found to be irrelevant, and to clarify questions that were confusing. The revised test, reproduced in Appendix B, contained 23 multiple-choice questions, four completion questions, and six proofs to be completed. Due to multiple answers for some questions, the total possible score was 62.

Three main hypotheses were tested in Experiment II. It was hypothesized that the active-experimenter condition would be superior to the passive-experimenter condition, that the maximum-information condition would be superior to the minimum-information condition, and that the effects of the variables would be cumulative (i.e., that the active-experimenter-with-maximum-information condition would be superior to all other possible conditions).

Since the use of the additional materials by subjects in the active-experimenter conditions might be responsible for any superiority over the passive-experimenter condition, it was decided that an independent measure of the effect of these additional materials was necessary. Two passive-experimenter conditions were established, one in which subjects received the additional materials and one in which they did not. Therefore, a fourth hypothesis was that, of the two passive-experimenter conditions, the one with the additional materials would be superior to the one without.

Four treatment conditions were formed, then, to test the hypotheses:

(1) Passive Experimenter, without additional materials
(2) Passive Experimenter, with additional materials
(3) Active Experimenter, minimum information, additional materials optional
(4) Active Experimenter, maximum information, additional materials optional

A. Method

1. Subjects. Students in four high school geometry classes, two classes in each of two high schools, served as subjects. Of the original 112 students in the class, eight were eliminated from the study because of incomplete data, resulting in a total sample of 104 subjects. The subjects were given the pretest used in Experiment I, and aptitude-test scores were obtained from school records. The subjects were randomly assigned to the four treatment conditions, within each classroom.

2. Materials. The geometry program was bound into ten booklets, with an answer sheet on the front of each booklet and instructions at the back. Each subject was given one booklet per 50 minutes of class time. A diagnostic quiz, with special answer sheet, followed the instructional materials in the booklets. In this experiment, no computer or special response devices were used.

3. Procedures. Each day, subjects in the two passive-experimenter conditions were given their materials and sent to adjacent classrooms--study halls or unused rooms. Subjects in the condition with passive experimenter and with additional materials were given both the program booklet and the additional materials, and could use both as they saw fit. Subjects in the condition with passive experimenter but without additional materials were given only the program booklet.

Subjects in the active-experimenter conditions remained in their regular classrooms and were given program booklets. For the maximum-information condition, an instruction sheet at the end of the booklet told the subject to raise his hand when he had completed the diagnostic quiz, and to show the quiz answer sheet to his teacher. For the minimum-information condition, the instruction sheet told the subject to review any portion of the program that

related to his errors on the diagnostic quiz. This defined the difference between the maximum- and minimum-information conditions: subjects in the maximum-information condition were obliged to inform the experimenter of their progress, while those in the minimum-information condition could inform the experimenter if they chose to. Experimenters gave subjects the additional materials when they thought it appropriate to do so, and could aid the students in any other way they wished.

4. Experimenters. Four high-school geometry teachers used as experimenters in Experiment II were given special training in the nature of the experiment and procedures to be followed during the study. One teacher was the one used in Experiment I. All four teachers had taught geometry for more than 10 years.

B. Results

Table 2 contains the means and standard deviations for the aptitude test scores, number of contacts with the experimenter, and posttest scores for the four treatment conditions. Table 4 shows the results of Sheffe's S-test for multiple comparisons for the hypotheses. Note that the comparison of conditions 1 and 2 provides an independent estimate of the effects of the additional materials.

As in Experiment I, none of the hypotheses received support. There is no recognizable benefit from having an active teacher in the classroom, and providing a teacher with information about subject performances does not result in superior posttest scores. This is true even though the maximum information condition caused the experimenters to have almost twice as many contacts with subjects as did the minimum information condition (208 contacts vs. 108 contacts). In addition, providing subjects with additional instructional materials failed to increase learning.

VI. DISCUSSION

A. Effects of Teachers

Data from both experiments indicate that the teachers were not able to make any positive contribution to student learning in the programmed learning situation. Indeed, nonsignificant trends suggest that active intervention by the teachers may actually have interfered with the effectiveness of the program. One possible explanation for these findings is that the variables studied are, in fact, unimportant in classroom applications of programmed instruction. This answer cannot be rejected at the present time, although it seems unlikely on the basis of general observations and common classroom experiences.

There are at least three other possible explanations for the lack of significant teacher effects in the present study: (1) teachers were not sufficiently familiar or sympathetic with their new role, or with the unconventional materials and procedures, to work effectively in the experimental environment; (2) the teachers did not have enough time with each student; (3) the teachers were used in a role that did not make full use of their capabilities.

Data from one of the teachers tend to refute the first explanation. This teacher, who served as the only experimenter in Experiment I, and one of the four experimenters in Experiment II, had participated in the original writing of the geometry program. He was completely sympathetic with the instructional approach used in the study, and thoroughly familiar with the program and with the associated procedures, yet he was no more successful than the other three teachers in aiding student learning.

The second explanation, insufficient time for teachers to work with the students, may be at least part of the answer. With 20 students in the room, a teacher has, on the average, only three minutes out of each hour to work with each student. At least half of this time must probably be spent in monitoring the students' performance and in deciding what remedial actions should be taken, leaving only one and a half minutes for actual face-to-face interaction with each student. Perhaps a teacher cannot be expected to have much impact on programmed learning under these conditions.

Finally, it may be that the teachers were forced into a role that did not make best use of their capabilities. The program used in this study had been developed for independent study, so the teachers were required to adapt their own behavior to an instructional configuration that made no provision for them. It is reasonable to conjecture that teachers can play an effective part in programmed instruction only when their role has been developed as an integral, interacting part of the total instructional system including the students, the program, and any other classroom resources. The same iterative trial-and-revision procedures used to develop effective programs should now be applied to the entire system. This might involve working with several experimental classrooms, and manipulating, simultaneously or independently, the teacher's role, the students' social structure and study practices, and the program itself. Through this lesson-shaping or "engineering" approach, the various parts of the system would be gradually modified until the system consistently accomplished its teaching objectives with successive samples of the target student population.

B. Effects of Student Control

In view of the observation that subjects practically never used their optional control capability, it is not surprising that this variable had no significant effect on learning in Experiment I. A new question arises, however: Why did the subjects not choose to exercise their branching prerogatives? One possible explanation is that they thought they were doing well enough with the original preprogrammed sequence, but such optimism would have been in clear conflict with the actual performance of a number of subjects on both the criterion test and the diagnostic items in the program itself.

Two other explanations seem more reasonable. One is that the subjects were more concerned with completing the program than they were with the amount they were learning along the way. This tendency has been observed in several

Table 3

Means and Standard Deviations of Aptitude Scores, Experimenter Contacts, and Posttest Scores for the Four Treatment Conditions (Experiment II)

School A

Treatment Condition	N		Aptitude Scores*	Experimenter Contacts	Posttest Scores
(1) Passive E, No additional materials	12	Mean	111.66	-	34.00
		SD	11.52		10.40
(2) Passive E, Additional materials	12	Mean	112.50	-	31.75
		SD	13.45		7.22
(3) Active E, Minimum information	14	Mean	111.00	58	35.92
		SD	11.11	-	6.54
(4) Active E, Maximum information	13	Mean	112.38	125	30.46
		SD	9.27	-	7.49

*IQ scores

School B

(1) Passive E, No additional materials	13	Mean	6.84**	-	31.15
		SD	1.45		11.44
(2) Passive E, Additional materials	13	Mean	6.53	-	28.38
		SD	1.21		8.06
(3) Active E, Minimum information	14	Mean	6.71	50	29.07
		SD	1.16	-	9.13
(4) Active E, Maximum information	13	Mean	6.76	83	28.15
		SD	1.18	-	8.03

**Stanine scores

Table 4

Sheffe's S-Test for Multiple Comparisons of Posttest Scores for the Four Treatment Conditions (Experiment II)

Treatments and Means			
(1)	(2)	(3)	(4)
32.52	30.00	32.50	29.30

Comparison	d	s_d	t*
1, 2 vs. 3, 4 (passive vs. active)	.36	1.79	.201
3 vs. 4 (min. vs. max. information)	3.20	2.48	1.290
1,2, 3 vs. 4 (cumulative effects)	2.37	2.06	1.150
1 vs. 2 (additional materials)	2.52	2.58	.976

*t must be greater than 2.85 for a significant difference with $\alpha = .05$

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earlier studies, but no completely effective procedure has been developed for making the subjects more self-critical about their own learning as they proceed through the program. A partial solution in some situations has been to use preprogrammed remedial loops as a "penalty" for incorrect responses on diagnostic items, so that subjects know they will be given long remedial sequences later in the program if they do not master the earlier topics. Possibly this approach could have been used more extensively in the present study to increase the subjects' motivation to use the optional control capabilities to review earlier materials on which they felt weak.

Another possible explanation for the failure to use the student control capability is that the branching format and procedures offered to the subjects were restrictive and unnatural. If they had been allowed to ask questions in a natural-language format, similar to the free-discussion, give-and-take interactions that are possible between a pupil and a tutor, they might have made more use of the capability of reviewing earlier topics. Research currently being planned at System Development Corporation will provide some evidence to confirm or refute this hypothesis.

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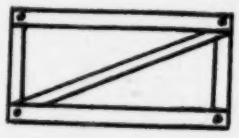
APPENDIX A

GEOMETRY PRETEST IN TWO PARTS: PART A TESTS KNOWLEDGE OF PREREQUISITE SKILLS, AND PART B TESTS SKILLS COVERED IN THE PROGRAM.

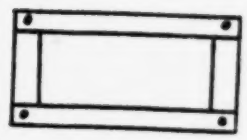
TEST A

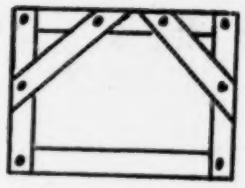
This is a test of some areas of geometric and algebraic knowledge. You have studied most of the material tested, but some of it may be new to you. Do not spend too much time on a question. Skip over questions that are too difficult and come back to them later if you have time. Work as fast as you can, but not so fast you make mistakes. Your score will be the number of questions answered correctly. There are 31 questions, some multiple choice and some fill-in. For the multiple-choice questions, circle the number of your answer.

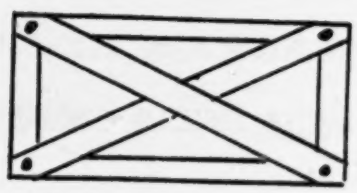
1. Which of the following shapes is NOT rigid?

1. 

2.

3. 

4. 

5. 

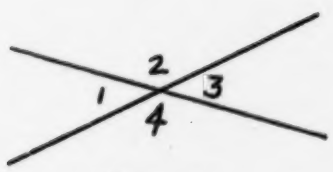


Fig. A

Fig. B

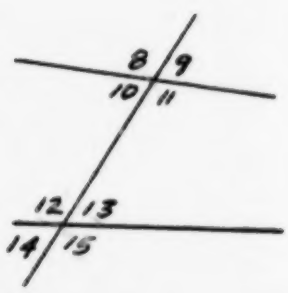


Fig. C

2. In Fig. A, $\angle 1 = 30^\circ$.

3. In Fig. A, $\angle 3 + \angle 4 = ?$

4. In Fig. B, $\angle 5 + \angle 6 = 145^\circ$.

5. In Fig. C, $\angle 14 = 45^\circ$

$\angle 3 =$ _____ degrees

_____ degrees

$\angle 7 =$ _____ degrees

$\angle 12 =$ _____ degrees

6. $T + 6 = Z + 6$

7. $X + 4 = Y$

8. $R = Mt$

9. $5 - a = 6 - b$

10. $K = \frac{5 + N}{2}$

T = _____.

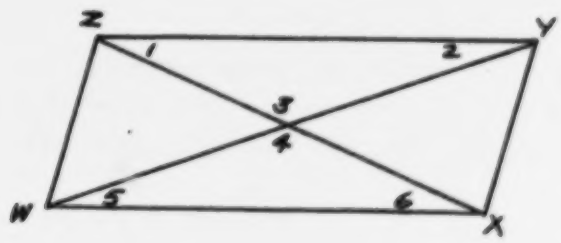
X = _____.

M = _____.

b = _____.

N = _____.

11. Given: ▱ WXYZ as shown. Which of the following is true?

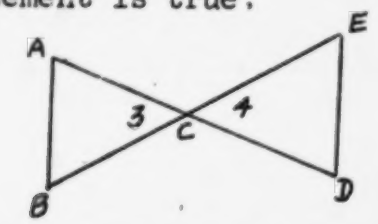


1. ∠5 = ∠6
2. ∠4 + ∠1 + ∠2 = 180°
3. WXY is bisected by ZX
4. ∠4 = ∠1 + ∠2

12. Now imagine a ▱ WXYZ labeled as shown but whose sides might be longer or shorter and whose angles might be changed while remaining a parallelogram. Which of the following could <u>NEVER</u> be true?

1. ∠1 = ∠2
2. ∠1 = ∠5
3. WXY is bisected by ZX
4. ∠2 = ∠3
5. WZ bisected by WY

Read the following problem carefully. On the line after each statement, write the <u>letter</u> of the fact (given in the box below) that tells the reason why the statement is true.



Given: AD bisects BE
BE bisects AD

To Prove: △ ACB ≅ △ ECD

a. If two lines are perpendicular to each other, they form right angles.
b. If a side of one triangle is the same line as the side of another triangle, then these two sides are equal.
c. When two straight lines intersect, vertical angles are formed.
d. The midpoint of a line divides the line into two equal parts.
e. All right angles are equal.
f. If two sides and the angle between them in one triangle are equal to two sides and the angle between them in another triangle, then the triangles are congruent.
g. Vertical angles are equal.
h. When one line bisects another, it divides it into two equal parts.
i. If two angles and the side between them in one triangle are equal to two angles and the side between them in another triangle, then the triangles are congruent.

13. Angle 3 and angle 4 are vertical angles. Why? _____.

14. Angle 3 equals angle 4. Why? _____.

15. AC = CD. Why? _____.

16. BC = CE. Why? _____.

17. △ ACB ≅ △ ECD. Why? _____.

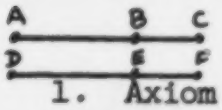
Here are some axioms:

1. If things that are equal are added to things that are equal, the sums are =.
2. If things that are = are subtracted from things that are =, the differences are =.
3. Doubles of equals are =.
4. Halves of equals are =.
5. Things = to the same thing are = to each other.

Each of the statements #18-#21 is true <u>because of</u> one of the axioms. Pick the axiom which makes the statement true.

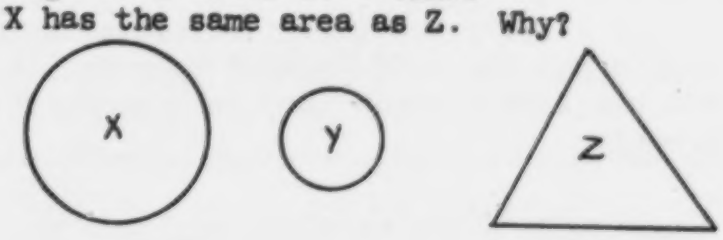
18. If r = s, and r = v, then s = v. This is true because of
    1. Axiom 1
    2. Axiom 2
    3. Axiom 3
    4. Axiom 4
    5. Axiom 5

19. If j = k, then 5 - j = 5 - k. This is true because of
    1. Axiom 1
    2. Axiom 2
    3. Axiom 3
    4. Axiom 4
    5. Axiom 5

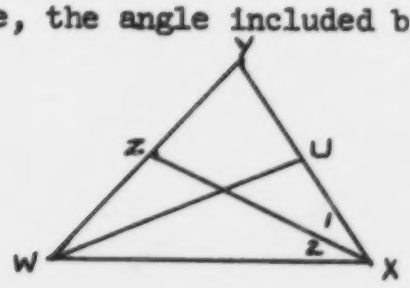
20. 

If AB = DE, and if AC is twice AB and DF is twice DE, why is AC = DF?
    1. Axiom 1
    2. Axiom 2
    3. Axiom 3
    4. Axiom 4
    5. Axiom 5

21. If X is 4 times as large as Y and Z is 4 times as large as Y, then X has the same area as Z. Why?
    1. Axiom 1
    2. Axiom 2
    3. Axiom 3
    4. Axiom 4
    5. Axiom 5

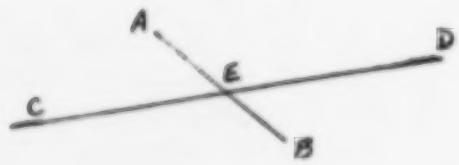


22. In the figure opposite, the angle included by sides YX and ZX is
    1. 1
    2. 2
    3. X
    4. Y
    5. U



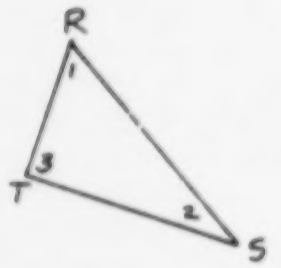
23. "A geometric figure formed by three straight lines meeting at three points and with no two sides equal" defines
    1. a perimeter
    2. an obtuse triangle
    3. an isosceles triangle
    4. a scalene triangle
    5. none of the above

24. AB bisects CD. Therefore ____ = ____.



25. If RT = TS, which angles are equal? _____.

26. If RS = ST, which angles are equal? _____.



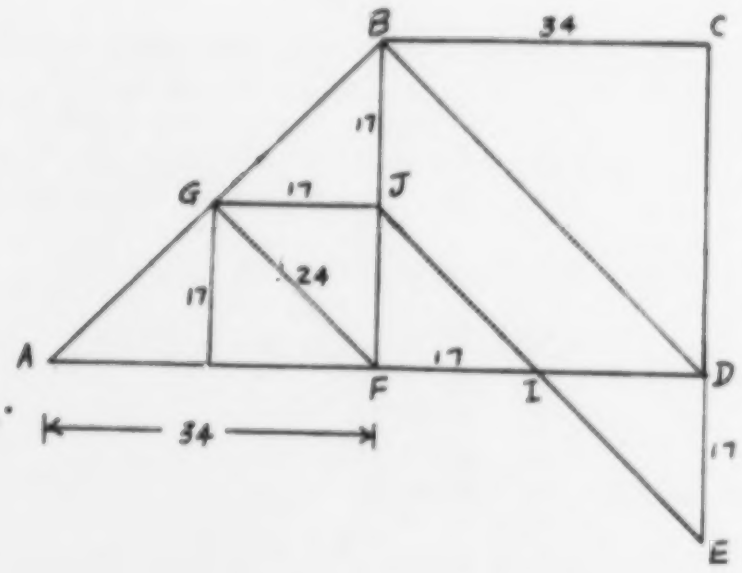
27. How long is HF? ____.

28. How long is BF? ____.

29. How long is ID? ____.

30. How long is CE? ____.

31. If AG is 24, how long is AB? ____.

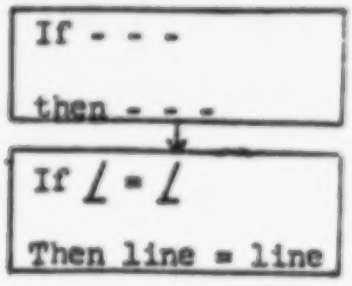


TEST B

This is a test of some areas of geometric knowledge. You may have studied some of the material tested, but most of it may be new to you. Do not spend too much time on any question. Skip over questions that are too difficult and come back to them later if you have time. Work as fast as you can, but not so fast you make mistakes. Your score will be the number of questions answered correctly. There are 23 questions, some multiple choice and some fill-in. For the multiple choice questions, circle the number of your answer.

1. Which of the following has conclusion contents: line < line?
   1. Radii of same circle =.
   2. Trichotomy axiom.
   3. St. line shortest distance between 2 pts.
   4. In a triangle, side < sum of other sides.

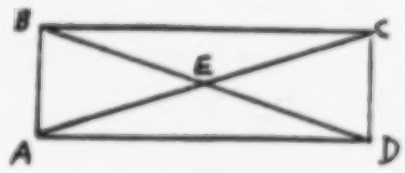
2. Which of the following statements could NOT be used as the missing step in the proof to the right?
   1. If straight $\angle$ s, then $\angle = \angle$
   2. If isosceles triangle, then $\angle = \angle$
   3. If line = line, then $\angle = \angle$
   4. If $\angle = \angle$, then line = line
   5. If $\angle = \angle$, then $\angle = \angle$



3. Pick out the one idea whose conclusion contents are NOT $\angle$ = sum of $\angle$ s.
   1. In a triangle, exterior $\angle$ = sum of remote interior $\angle$ s.
   2. Whole = sum of its parts.
   3. A bisector divides an $\angle$ into 2 = parts.
   4. One st. $\angle$ (180°) = sum of interior $\angle$ s of triangle.

4. IDEA: $\neq + \neq \rightarrow \neq$ of same order

   APPLICATION: If AE > ED and _____, then AC > BD.
   1. AE > EC
   2. EC > BE
   3. BE > ED
   4. BE > EC



5. r > s and l < m. Combine these two statements by addition.
   1. r + l > m + s
   2. r + l < m + s
   3. r + m > s + l
   4. r + m < s + l
   5. answer not given

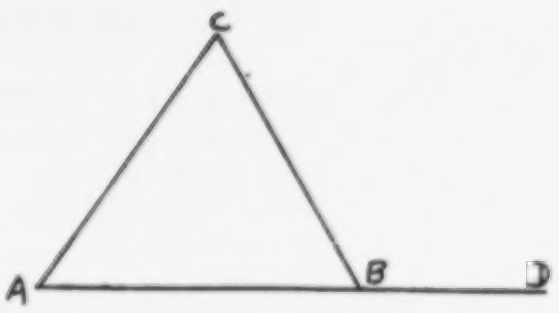
6. The possible relationship between the populations of California and New York may be expressed in 4 ways:

   C > N; C < N ; C = N ; C ≠ N

   What is the greatest number of these statements that can be true at the same time?
   1. One statement
   2. Two statements
   3. Three statements
   4. Four statements

7. If unequals are added to unequals of the same order, the sums are:
   1. equal in the same order.
   2. unequal in the same order.
   3. equal in the opposite order.
   4. unequal in the opposite order.
   5. it is not possible to say definitely.

8. Given: △ABC with side AB extended to D.
   Under which of the following conditions would ∠CBD < ∠ACB ?
   1. if ∠C is acute.
   2. if ∠CBA is obtuse.
   3. if ∠C is a right angle.
   4. if ∠A is acute.
   5. none of the above conditions.

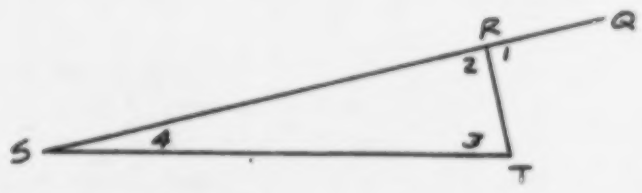


9. If we know that the statements r > u and r < u are both false, why is it true that r = u ?
   1. Transitive axiom.
   2. logical order law.
   3. Trichotomy axiom.
   4. the whole is greater than a part.
   5. ≠ + ≠ gives ≠ .

10. "Base angles of an isosceles trapezoid are equal."
    What are the hypotheses contents of this statement?
    1. ∠ = ∠
    2. isosceles trapezoid, ∠ = ∠
    3. trapezoid
    4. isosceles trapezoid

11. If x > y and a = b, why is x + a > y + b ?
    1. equals added to unequals gives unequals in the same order.
    2. unequals added to unequals gives unequals in the same order.
    3. transitive axiom.
    4. substitution.
    5. trichotomy axiom.

12. ∠3 has the same measure (size) as which of the following?
    1. ∠2 + ∠4
    2. ∠3 + ∠4
    3. ∠1 - ∠4
    4. ∠2 - ∠4
    5. answer not given

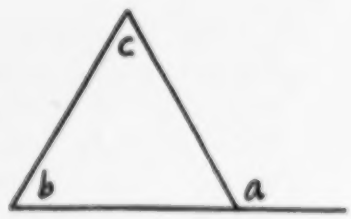


13. If this is a step in a proof:

If ∠a = ∠b
Then AC = AB

    What must the conclusion of the Previous statement in the proof be?
    1. line = line
    2. AC = AB
    3. ∠a = ∠b
    4. not enough information given to tell

14. Why is ∠a never equal to either ∠b or ∠c ?



1. In a △, the larger ∠ is opposite the larger side.
2. In a △, the larger side is opposite the larger ∠.
3. The whole is > any part.
4. Transitive Axiom.
5. Exterior ∠ > either remote interior ∠.

15. "A geometry statement has both a hypothesis and a conclusion."
How often is this true?
1. sometimes
2. always
3. never

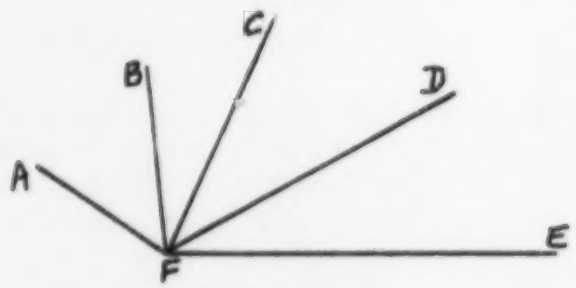
16. The contents of a geometry statement are important because they give us
1. elements and their relationship
2. ideas
3. lines and angles
4. conclusions

17. When comparing any two sides in a triangle, the longer side is
1. longer.
2. next to the shorter side.
3. formed by the larger angle.
4. opposite the larger angle.

18. Given: $\angle AFC = \angle CFE$, and $\angle DFE < \angle AFB$.

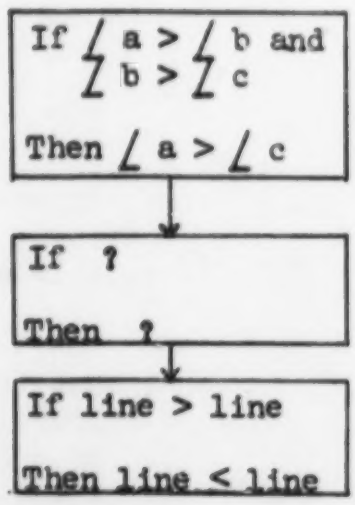
Then which of these statements is true?

1. $\angle BFC > \angle CFD$
2. $\angle CFB = \angle CFD$
3. $\angle CFD > \angle BFC$
4. $\angle AFD < \angle BFE$
5. $\angle DFC < \angle CFB$



19. What is the missing step in the proof below?

1. If ∠a > ∠c then line > line
2. If ∠a > ∠b and ∠b > ∠c then line > line
3. If line > line then ∠a > ∠c
4. If ∠b > ∠c then line > line



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20. What is another way of showing that X < Y ?
    1. X < Y
    2. Y > X
    3. Y < X
    4. Y = X

21. In which of the following spaces would the conclusion of a geometric statement belong?
    1. If_____.
    2. Prove:_____.
    3. Given:_____.
    4. Hypothesis:_____.

22. When we "strip" a geometric statement, we are looking for its
    1. hypothesis
    2. ideas
    3. contents
    4. lines and angles

23. If x > y
    and m = n

    then x/m ? y/n

    1. >
    2. <
    3. =
    4. can't say definitely

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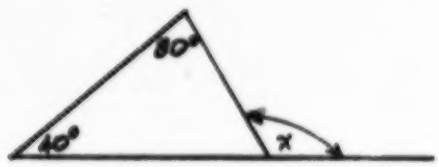
APPENDIX B

GEOMETRY CRITERION POSTTEST

GEOMETRY TEST

1. Using the sketch, $\angle x = 120^\circ$ because _____?_____.

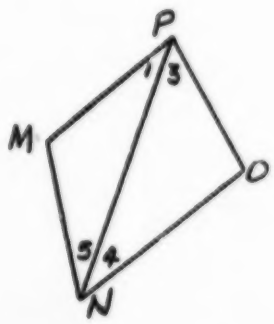


   1. Exterior $\angle$ of a Δ > either remote interior $\angle$.
   2. Whole = sum of its parts.
   3. Sum of $\angle$s of a $\Delta = 180^\circ$.
   4. Exterior $\angle$ of a Δ = sum of all the interior $\angle$s.
   5. Exterior $\angle$ of a Δ = sum of its remote interior $\angle$s.

2. How long is the hypotenuse of a right triangle?

   1. Always the longest side.
   2. Sometimes the longest side.
   3. Usually next to longest side.
   4. There is always a longer side.
   5. There is not a definite answer.

3. If $\angle MPO > \angle ONM$, and $\angle 1 = \angle 4$, then $\angle 3$ __?__ $\angle 5$.

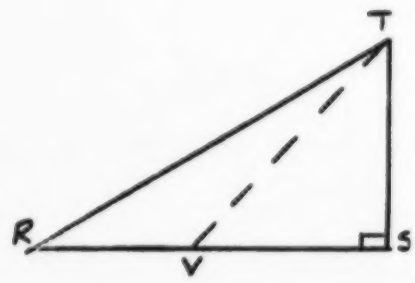


   1. >
   2. <
   3. =
   4. Can't say definitely.

4. Consider the following statements when only positive numbers are used. Circle the number of each statement that is false.

   1. = + ≠ gives ≠ of same order.
   2. = - ≠ gives ≠ of same order.
   3. = x ≠ gives ≠ of same order.
   4. = ÷ ≠ gives ≠ of same order.
   5. All statements are true.

5. Given right Δ RST as shown, and any point "V" on segment RS. If segment TV is drawn, it may be concluded that TV < TR and $\angle$ TVS > $\angle$ TRV. Under which of the following changes would the above conclusions no longer have to be true?



   1. If Δ RTS is isosceles, with base $\angle$s "R" and "S" equal.
   2. If $\angle$ S is obtuse.
   3. If point "V" lies on an extension of RS.
   4. If $\angle$ T is a right $\angle$ and TR > TS.
   5. If $\angle$ S is acute and TR > TS.

6. Given: the numbers A, B, C, and D are positive.
If A = B and C > D, then A - C < B - D, because ___?___.

1. = - = gives ≠ of same order.
2. = - ≠ gives ≠ of opposite order.
3. ≠ - ≠ gives ≠ of opposite order.
4. = + ≠ gives ≠ of opposite order.
5. = - ≠ gives ≠ of same order.

7. If m ≠ y, and m is not < y, then ___?___.

1. m > y
2. m < y
3. m = y
4. Can't say definitely.

8. If $\frac{m + n}{p} < 5$, what is the value of m + n, when m, n, p are all positive?

1. m + n = 5 + p
2. m + n > 5 - p
3. m + n < 5p
4. m + n < 5 - p
5. Can't say definitely.

9. Which one of the following statements is the <u>most</u> <u>complete</u> and <u>also</u> <u>true</u> descriptions of these inequalities?

a > b; b < a

1. They have different meanings and they have the opposite order.
2. They have different meanings and they have the same order.
3. They have different meanings.
4. They have the same meaning.
5. They have the same order.

10. In drawing a sketch for a problem starting with the phrase, "In a triangle..." what kind of triangle would be best to draw?

1. right
2. scalene
3. isosceles
4. equilateral
5. obtuse

11. Which of the following illustrates a compound hypothesis?

1. Given: A, B, C, D, and E.
2. If C > A and D < E, ...
3. If K is the intersection of lines p_1, p_2, p_3, and p_4.
4. Prove: R > S and T < V.
5. More than one of the above illustrates a compound hypothesis.

12. "Line > line, line = line, or line < line" are the conclusion Core of ?.

1. In a Δ, if $\angle > \angle$, then side > side.
2. Whole > any of its parts.
3. Transitive Axiom.
4. Trichotomy Axiom.
5. Whole = sum of its parts.

13. Which of the following is the only one whose conclusion Core CANNOT be used for both angles and lines?

1. Whole = sum of its parts.
2. Transitive Axiom.
3. = + ≠ gives ≠ of same order.
4. In a triangle, if $\angle = \angle$, then side = side.
5. Trichotomy Axiom.

14. Which of the following could not have $\angle \neq \angle$ as its conclusion Core?

1. Trichotomy Axiom.
2. Whole > any of its parts.
3. Transitive Axiom.
4. ≠ - = gives ≠ of same order.

15. Which of the numbered Ideas below belongs with the list at the right?

1. Whole = sum of its parts.
2. In a Δ, exterior $\angle$ = sum of its remote interior $\angle$s.
3. = x = gives = .
4. Trichotomy Axiom.
5. In a Δ, if side > side, then $\angle > \angle$.

Base $\angle$s of an isosceles Δ are = .

An equilateral Δ is equiangular.

= + = gives = .

A bisector divides an $\angle$ into two = parts.

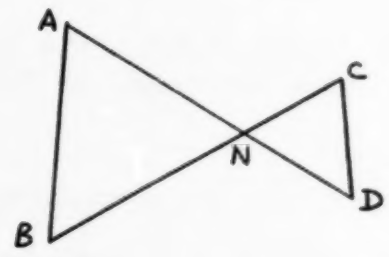
16. Which of the lettered statements at the right have conclusion Cores of "$\angle = \angle$."

1. All of them
2. A, C, and E
3. A, C, and D
4. A, B, C, and D
5. C, D, and E
6. A, D
7. C, E

A. Transitive Axiom of equality.
B. In a Δ, if $\angle = \angle$, then side = side.
C. = ÷ = are =.
D. Base $\angle$s of an isosceles Δ are =.
E. Whole = sum of its parts.

17. If BN > ND and AD = BC, what is the conclusion Core of = - ≠ gives ≠ of opposite order?

1. NC < ND
2. AN < ND
3. AN < NC
4. AN > NC



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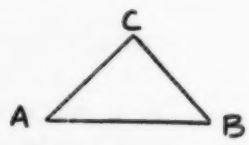
1. If there is an isosceles Δ.
2. Base $\angle$s of an isosceles Δ are =.
3. If AC = CB, then $\angle$ A = $\angle$ B.
4. Two lines, two angles.
5. If line = line, then $\angle = \angle$.



Each of the statements above illustrates something that was given a special name in the program. Select the best one for each term below.

18. # ___?___ illustrates the term "CORE."

19. # ___?___ illustrates the term "ELEMENTS."

20. # ___?___ illustrates the term "APPLICATION."

21. # ___?___ illustrates the term "IDEA."

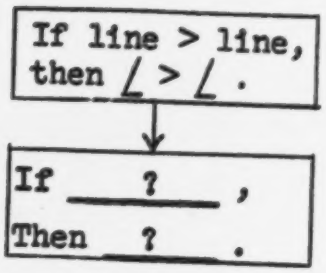
---

22. If this is a step in a proof, then the hypothesis of the next step must contain ___?___.

If $\angle > \angle$,
then side > side.

1. $\angle > \angle$
2. side > side
3. $\angle > \angle$ and side > side
4. Not enough information is given to tell.

23. How many of the following Ideas could be used to discover the unknown step in the proof?



A. Hypotenuse of rt. Δ > either leg.
B. If one ∠ of Δ > another ∠ , then side > side.
C. In a Δ , side < sum of other sides.
D. Ext. ∠ of Δ > its remote int. ∠ .

1. one
2. two
3. three
4. four
5. five

---

24. What is the hypothesis of the Trichotomy Axiom: "A quantity is equal to, greater than, or less than a second quantity of the same kind?"

Hypothesis: ___?___

---

25. State the Cores of the following Idea:

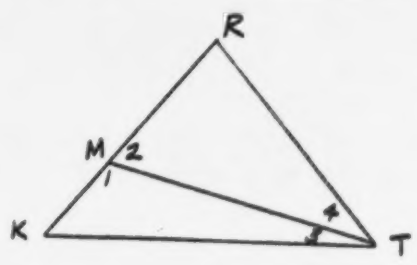
"The diagonals of a rhombus are perpendicular to each other."

Hypothesis Core: ___?___
Conclusion Core: ___?___

---

26. IDEA: If 2 sides of a Δ are ≠ , then the opposite ∠s are ≠ with the larger ∠ opposite the larger side.

APPLICATION: If ___?___ , then ∠ 1 > ∠ K.



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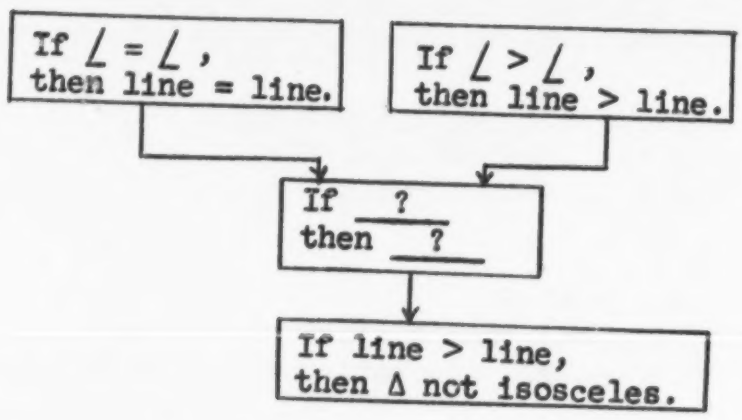
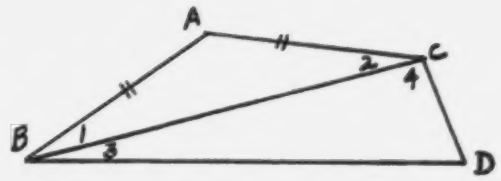
27. Supply a statement that would satisfy the "linking" requirements for the portion of the proof shown on the right. (Note: write the correct geometric elements into your answer.)



28. Complete the following proof.

GIVEN: $\triangle ABC$ is isosceles; $AB = BC$; $\angle 4 > \angle 3$.

PROVE: $\angle ACD > \angle ABD$.

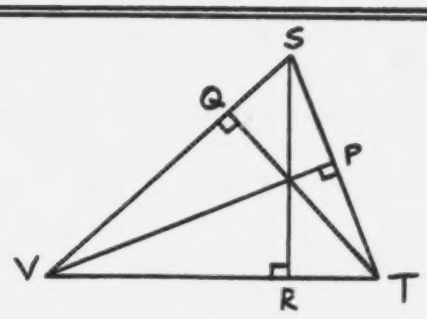


1. $\angle 4 > \angle 3$.	1. Given.
2. $\angle 2 = \angle 1$.	2. ?
3. ?	3. ?
4. ?	4. ?

29. Complete the following proof.

GIVEN: $\triangle VST$, with altitudes QT, PV, and RS as shown. (An alt. is perp. to side to which it is drawn.)

PROVE: $VS + ST + VT > VP + QT + SR$.

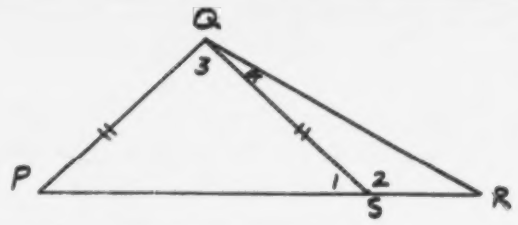


1. $\triangle VQT$, $\triangle VSP$, and $\triangle SRT$ are right triangles.	1. Perps. form rt. $\angle$s at P, Q, and R. Any $\triangle$ with rt. $\angle$ is rt. $\triangle$.
2. ?	2. ?
(etc.)	(etc.)

30. Complete the following proof.

GIVEN: $\triangle PQR$; $PQ = QS$.

PROVE: $\angle P > \angle R$.



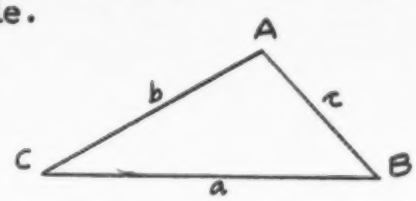
1. $\triangle PQR$; $PQ = QS$.	1. Given.
2. ?	2. ?
(etc.)	(etc.)

31. Complete the following proof.

PROBLEM: Prove that one side of a triangle is always less than the semiperimeter of the triangle.

GIVEN: $\triangle ABC$, with sides a, b, c.

PROVE: $a < \frac{a + b + c}{2}$.



1. $\triangle ABC$, with sides a, b, c.	1. Given.
2. $b + c > a$.	2. ?
3. $\frac{b + c}{2} > \frac{a}{2}$.	3. ?
4. $\frac{b + c}{2} + \frac{a}{2} > \frac{a}{2} + \frac{a}{2}$.	4. ?
5. $\frac{a + b + c}{2} > a$.	5. ?

32. In Δ ABC, AB = AC. Extend AB beyond point B. Next, choose "D" as some point on that extension. Then, draw line CD. Finally, prove ∠ ACD > ∠ D.

Directions: Draw and label a sketch in the provided box. Next, complete the proof, which is started below. It requires exactly six steps, including step 4, which is a "clue."

GIVEN: Δ ABC; AB = AC; D is an extension of AB.

PROVE: ∠ ACD > ∠ D.

Sketch

?

1. Δ ABC; AB = AC; D is an extension of AB.	1. Given.
2. ?	2. ?
3. ?	3. ?
4. ∠ ACB > ∠ D.	4. ?
5. ?	5. ?
6. ∠ ACD > ∠ D.	6. ?

33. Problem: ABC is a Δ in which side AB is greater than side AC. The bisectors of ∠ B and ∠ C are drawn, extending just to their point of intersection, O. Prove that OB ≠ OC.

Directions: (1) Draw and label an "accurate" sketch in the box.
(2) In order to prove that OB ≠ OC, you must prove either that OB > OC or else that OB < OC. By examining your sketch, decide which should be correct and write it in the PROVE blank.
(3) Complete the formal proof.

GIVEN: Δ ABC; OB bisects ∠ B; OC bisects ∠ C.

PROVE: ?

Sketch

?

1. Δ ABC; OB bisects ∠ B; OC bisects ∠ C.	1. Given.

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